V. *On the terms Force and Energy.* By C. LLOYD MORGAN, Esq., Assoc. R.S.M., F.G.S.

[Read 1879, Nov. 26.]

Abstract.

At the outset the chief generalizations of the "Modern Science of Energy" were pointed out.

Energy is defined as the *power of doing work;* and this may be measured by multiplying the mass moved into the space moved through. Two forms of energy are recognized by physicists, *Actual Energy* and *Potential Energy.* Take the case of a swinging pendulum. At the end of each swing, in the transient moment of rest, all the energy is potential; in the lowest position of the "bob" all the energy is actual. In the one case the pendulum can do work by virtue of its position: in the other case it can do work by virtue of its impetus. In other words, the pendulum has potential energy by virtue of its *possible motion;* it has actual energy by virtue of its *actual motion.*

Transformation of Energy. Energy may result from the motion of masses or the motion of molecules. The motion of masses may under suitable conditions be transformed into the motion of molecules, and one kind of molecular motion may be transformed into other kinds. For example, chemical action in a battery, or heat in a thermopyle, may be transformed into electricity: this electricity may be made to take on the form of an electric spark, giving rise to sound, heat, and light, or it may be made to effect chemical decomposition, or again in the electric engine it may be made to raise a heavy weight, the visible motion of which in its fall will, as it strikes the earth, be converted into audible pulses of the atmosphere and into the invisible motion of heat.

Conservation of Energy. Throughout all its transformations energy remains constant in quantity. It may at one time exist as potential energy, in the stone for example that projected from the hand hesitates as it were for a moment before it falls again to the earth; at another time as actual energy, in the same stone for instance as it is actually falling through space; and once more as molecular energy when the stone comes to rest on the earth's surface and gives rise to the motion of molecules. But it always exists. We are never thrown into a state of intellectual confusion by the sudden disappearance of any quantity, however small, of the store of energy in the universe.

Dissipation of Energy. Transformations of energy take place more rapidly in some directions than in others. The result of this

is that all forms tend to be degraded to one (the lowest) form; and this lowest form is heat uniformly diffused throughout space.

Attention having been drawn to these generalizations, some of the confusions arising out of the ambiguity of the word *potential* were pointed out. The following statements of physicists were also commented on. Taking the case of an arrow about to be discharged from a fully-bent bow, one physicist says that the potential energy is in the bow; another describes the arrow as possessing potential energy; while a third speaks of the energy of the system of bow and arrow. To these may be added a fourth view, advocated in this paper, that the energy is in the force or forces concerned.

Force. There are two very distinct definitions of force.

I. *Force is any cause which tends to urge a material point in a definite direction and with a definite acceleration.* II. *Force is the rate at which an agent does work per unit of length.* In this paper the word force is used in the former sense.

Energy of Motion and Energy of Tension. In place of the terms actual energy and potential energy it has been proposed to use the terms energy of motion and energy of tension. Take the case of a ball fastened to one end of an india-rubber string. When the ball is thrown from the hand it has energy of motion: when, however, it is stopped by the stretched string the energy of motion has been converted into energy of tension in the india-rubber. This energy of tension is reconverted into energy of motion as the ball is brought back to the hand by the elasticity of the string. But what, it may be asked, is gained by the use of these terms? It avoids the ambiguity of the word potential. It avoids the confusion which is apt to arise when actual or possible *motion* is the thing regarded. It avoids such a definition as that of Clerk Maxwell, that potential energy signifies the energy which a system has not in actual possession but only has the power to acquire. It draws attention directly to the *force or forces which are in action*, and it leads us up to the truth that motion and tension are the two forms under which force makes itself known to us.

The Persistence of Force. According to the principle of the Conservation of Energy the total amount of energy in the universe remains unaltered. When analysed this conception comes to this; that the sum of the actual and possible motion of a constant quantity of matter is itself constant. But this actual or possible motion is not itself an existence, but only the sign of an existence. And the existence of which it is a sign is force. That is to say, the amount of motion being constant the amount of force which produces that motion must also be constant. This generalization is summed up in the expression Resistance of Force.

Amount of force and Intensity of force. The distinction between the amount of force and the intensity of force must not be lost sight of. They differ in this; that the intensity of force involves the element *time*, which is not involved in the amount of force. It is the amount not the intensity of force which is persistent. These positions in fact may be maintained: I. *Force is that which produces change of position.* II. *Intensity of force is measured by change of motion.* III. *Total amount of force is measured by total amount of change of position.*

Metaphysical Force. There is a tendency among modern physicists to set aside the conception of *force the cause of motion*, as a bit of mischievous metaphysics. The word force is only retained as a convenient expression for a *rate*. It is not a little strange that of two existences, both of which rest on the same basis *experience*, the one (matter) should be regarded as essentially physical, while the other (force) is looked upon as peculiarly metaphysical.

The two objective existences. We are constantly told that there are two things which have objective existences—Matter and Energy. Of these, one (matter) is simple, the other (energy) is compound. For the conception of energy involves the conception of the motion of matter through space. In both cases there is quantitative conservation. The amount of matter is constant. And the amount of actual or possible motion of that matter is also constant.

It is here maintained, however, that the two things which have objective existence are Matter and Force. Both of these are simple indecomposable existences. In both there is quantitative conservation. The amount of matter is constant. And the amount of force, manifested here as motion there as tension, is also constant.

Conclusion. In this paper the value of the principle of the Conservation of Energy is not called in question. As a practical working formula it is invaluable. Nor is it too much to say that through it many branches of physics have been raised to the level of exact sciences.

What is called in question is the statement, that Matter and Energy are the two ultimate physical existences and the Indestructibility of Matter and the Conservation of Energy are the fundamental laws of physical philosophy. And it is here submitted that the two ultimate physical existences are Matter and Force and that the fundamental laws of physical philosophy are the Indestructibility of Matter and the Persistence of Force. What we call Energy is a manifestation of force either under the form of motion or under that of tension. It is by the interaction of matter and force that the varied phenomena of the universe have been evolved.